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Abstract

Air pollutant emissions from aircraft have been subjected to less rigorous control than road traffic emissions, and the rapid growth of global aviation is a matter of concern in relation to human exposures to pollutants, and consequent effects upon health. Yim *et al* (2015 *Environ. Res. Lett.* **3** 034001) estimate exposures globally arising from aircraft engine emissions of primary particulate matter, and from secondary sulphates and ozone, and use concentration-response functions to calculate the impact upon mortality, which is monetised using the value of statistical life. This study makes a valuable contribution to estimating the magnitude of public health impact at various scales, ranging from local, near airport, regional and global. The results highlight the need to implement future mitigation actions to limit impacts of aviation upon air quality and public health. The approach adopted in Yim *et al* only accounts for the air pollutants emitted by aircraft engine exhausts. Whilst aircraft emissions are often considered as dominant near runways, there are a number of other sources and processes related to aviation that still need to be accounted for. This includes impacts of nitrate aerosol formed from NO_x emissions, but probably more important, are the other airport-related emissions from ground service equipment and road traffic. By inclusion of these, and consideration of non-fatal impacts, future research will generate comprehensive estimates of impact related to aviation and airports.

Sources related to transport of people and goods are amongst the largest emitters of locally-acting air pollutants, but are also often amongst the sources most amenable to control. Thus road traffic tail-pipe emissions in the developed world have declined over the past 20 years, despite a continuing growth in traffic volumes. Technology has delivered greatly reduced emissions of health-related pollutants per vehicle-kilometre, whilst simultaneously improving fuel efficiency and greenhouse gas emissions by a combination of improved engine technology and exhaust after-treatment. Until recently, emissions from shipping were largely unregulated and as a consequence were steadily increasing as a percentage of SO_2 and NO_x emissions (Eyring *et al* 2010). Recent international agreements have curbed emissions from shipping, especially in coastal waters and ports (Tao *et al* 2013), and the regulations are set to tighten further.

International aviation is generating a large interest within the scientific community because of its constant growth: in 2012, there were more than 79 million aircraft movements carrying 5.7 billion passengers between 1598 airports located in 159 countries (ACI 2013). Annual growth rates of ~5% per year are typical and numbers are predicted to double between 2012 and 2030 (ICAO 2013).

While most of the gas phase content of typical airliner engine exhaust consists of N_2, O_2, CO_2, and H_2O, many residual products are also jointly released in the atmosphere, including NO_x, CO, SO_2, a large number of hydrocarbons and aerosol particles containing organic and inorganic components having non-volatile and semi-volatile properties (Masiol and Harrison 2014). As from other combustion sources, the list of such products may also include compounds with known or suspected adverse effects on human health.

Furthermore, aviation accounts for around 1–2% of global greenhouse gas emissions per year.

While aviation has not been immune from the trend towards emissions reduction, it has thus far got away fairly lightly. For example, while automotive gasoline and diesel (with a volatility range similar to aviation fuels) have reduced to a sulphur content of <10 ppm, the limit for aviation fuel remains at 3000 ppm with actual concentrations reported to be within the range 300–1100 ppm. While automotive diesels sold in Europe now have to meet particle emission standards requiring the installation of a particle filter, jet engine emissions are still evaluated with a semi-quantitative 'smoke number' with little pressure to improve.

Amongst the transport sectors, aviation is more difficult to study and apportion as it encompasses both the horizontal and vertical dimensions. Nevertheless, while it is tempting to believe that the localization of ground and low altitude aircraft movements limits their impact on air quality, even the high altitude emissions can impact on air quality in the atmospheric boundary layer where people live and breathe (e.g., Barrett *et al* 2010). Therefore, impacts of aviation upon air quality and the assessment of related health effects are major questions currently addressed in scientific research and debated by policy-makers and stakeholders.

In this context, the paper by Yim *et al* (2015) is a valuable contribution toward the assessment of emissions and health effects of civil aviation. The study takes account of emissions of NO_x, hydrocarbons, SO_2, black carbon and organic carbon using dispersion and chemistry-transport models to calculate concentrations of fine particles ($PM_{2.5}$, primary plus secondary sulphate) and ozone. Its main strength is the multi-scale approach, which is capable to capture the impacts of civil aviation emissions at ground-level arising from dispersion at various scales, ranging from local (~1 km), near airport (~10 km), regional (~1000 km) and even global (~10 000 km). The study also estimates the premature mortality per year associated with population exposure to $PM_{2.5}$ and O_3 attributable to civil aviation emissions using concentration-response functions (CRF) reported in the literature. For $PM_{2.5}$ the CRF used in the WHO (2004) Global Burden of Disease study was used, as well as alternative CRF from more recent studies for sensitivity analysis. For O_3, a relative risk coefficient for respiratory mortality reported by Jerrett *et al* (2009) was applied. Furthermore, Yim *et al* monetised the estimated premature mortality impacts using country-specific values of statistical life (VSL) and compared these estimates with other societal costs of civil aviation, namely the global costs associated with aviation related accidents, climate and noise impacts. According to this methodology, a global total of ~5000 people who live within 20 km of airports are estimated to die prematurely each year due to long-term exposure to aviation-attributable $PM_{2.5}$ and O_3 with associated costs estimated to be ~$21 billion per year.

Despite the valuable contribution made by the paper by Yim *et al* it should be viewed as a starting point from which to focus forthcoming efforts to generate improved future estimates and to develop mitigation measures rather than a complete and comprehensive estimation. In fact, information on aviation impacts upon the environment and public health remain very sparse and many questions are still unresolved. In this context, the study of Yim *et al* is highly conservative and considers just direct aircraft emissions, omitting a large component of the ground-level aviation related emissions which may have potentially high impact on air quality at the surface. With this in mind, a list of future considerations that need to be addressed in future research should include:

- A comprehensive estimation of PM emissions, including both volatile and non-volatile phases and their partitioning and dilution effects at ambient temperatures. The study by Yim *et al* includes primary emissions of black carbon and particulate organic carbon calculated from fuel burn, and sulphate, estimated by a simple parameterization of sulphur dioxide oxidation. This is liable to underestimate $PM_{2.5}$ concentrations, as nitrate was omitted despite large emissions of precursor NO_x, and conversion of VOC to secondary organic aerosol, admittedly more difficult to model, is also left out. Work on automotive emissions has shown that the large semi-volatile hydrocarbon component of the emitted particles will tend to desorb with advection downwind of source and form a greater mass of secondary aerosol through oxidation (Robinson *et al* 2010).
- Aircraft non-exhaust and other airport-related emissions. While the work of Yim *et al* is restricted to engine emissions from aircraft, there is a strong case to extend the analysis to include other emissions and impacts associated with air traffic. Aircraft themselves also cause emissions from tyre, brake and runway wear. Within the airport, auxiliary and ground power units are widely in use to power stationary aircraft, and ground service equipment which often uses engine technologies and fuel of quality far inferior to modern road vehicles inevitably accompanies aircraft movements. Finally, and perhaps most importantly, airports both operate and attract large volumes of road traffic in the form of shuttle buses, taxis, private cars, service vehicles etc, which together generate a large pollutant load (Masiol and Harrison 2014) as well as greenhouse gas emissions and noise.
- An extended parameterization and assessment of health impacts. More recent CRFs are now available

in the literature, including coefficients used in the most recent Global Burden of Disease (2010) study (Lim et al 2012). Moreover, similar global burden studies have relied on Disability Adjusted Life Years (Lim et al 2012) or Years of Life Lost (Anenberg et al 2010), which are generally more appropriate metrics as they take into account the number of years lost due to ill-health. Additionally, the substantial burden of morbidity associated with air pollutant exposure should be included in further studies. Finally, although monetary valuation provides a common basis for comparison, there are ethical challenges around the valuation of non-market goods, such as ecosystem services, and the difference between VSL in high and low income countries (Hallegatte et al 2008).

Increasingly, cost-benefit analyses, taking account of the human health-related costs of industry and transport are being used to evaluate mitigation measures. It seems inevitable that civil aviation will continue to expand at a substantial rate and it will be essential to make sound decisions relating to its public health impacts. In this context, the work of Yim et al (2015) makes an important contribution and we look forward to further studies extending the analyses in the ways suggested above and being put to use in justifying proportionate mitigation measures.

References

ACI 2013 *ACI releases its 2012 World Airport Traffic Report* Media release Airports Council International Montreal (www.aci.aero/media/bc5239b4-07ac-4d1f-8cbb-db8f1b093d80/News/Releases/2013/PR_2013_08_28_WATR_Release_pdf)

Anenberg S C, Horowitz L W, Tong D Q and West J J 2010 An estimate of the global burden of anthropogenic ozone and fine particulate matter on premature human mortality using atmospheric modeling *Environ. Health Perspect.* **118** 1189–95

Barrett S R, Britter R E and Waitz I A 2010 Global mortality attributable to aircraft cruise emissions *Environ. Sci. Technol.* **44** 7736–42

Eyring V, Isaksen I S A, Berntsen T, Collins W J, Corbett J J, Endresen O, Grainger R G, Moldanova J, Schlager H and Stevenson D S 2010 Transport impacts on atmosphere and climate: shipping *Atmos. Environ.* **44** 4735–71

Hallegatte S, Henriet F and Corfee-Morlot J 2008 The Economics of climate change impacts and policy benefits at city scale: a conceptual framework *OECD Environment Working Papers,* No. 4 OECD Publishing doi:10.1787/230232725661

ICAO 2013 *Annual Report of the Council 2012* International Civil Aviation Organization (www.icao.int/publications/pages/publication.aspx?docnum=10001)

Jerrett M, Burnett R T, Pope C A, Ito K, Thurston G, Krewski D, Shi Y, Calle E and Thun M 2009 Long-term ozone exposure and mortality *New Engl. J. Med.* **360** 1085–95

Lim S S et al 2012 A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the global burden of disease study 2010 *Lancet* **380** 2224–60

Masiol M and Harrison R M 2014 Aircraft engine exhaust emissions and other airport-related contributions to ambient air pollution: a review *Atmos. Environ.* **95** 409–55

Robinson A L, Grieshop A P, Donahue N M and Hunt S W 2010 Updating the conceptual model for fine particle mass emissions from combustion systems *JAWMA* **60** 1204–22

Tao L, Fairley D, Kleeman M J and Harley R A 2013 Effects of switching to lower sulfur marine fuel oil on air quality in the San Francisco bay area *Environ. Sci. Technol.* **47** 10171–8

WHO 2004 World Health Organisation Global Burden of Disease (GBD) *World Health Organization Report* (accessed 24 February 2015 at www.who.int/healthinfo/global_burden_disease/2004_report_update/en/)

Yim S H L, Lee G L, Lee I W, Allroggen F, Ashok A, Caiazzo F, Eastham S D, Malina R and Barrett S R H 2015 Global, regional and local health impacts of civil aviation emissions *Environ. Res. Lett.* **3** 034001